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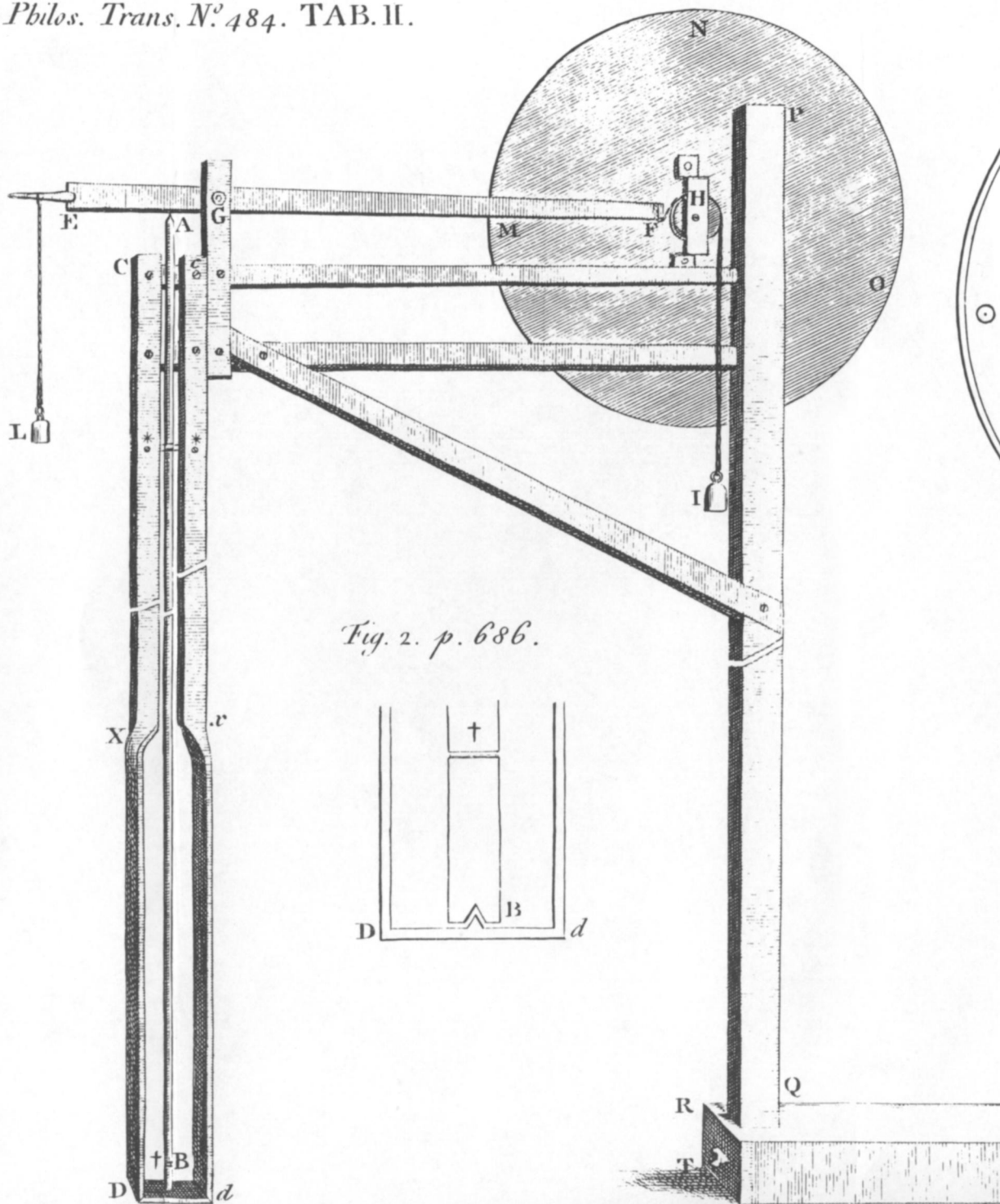
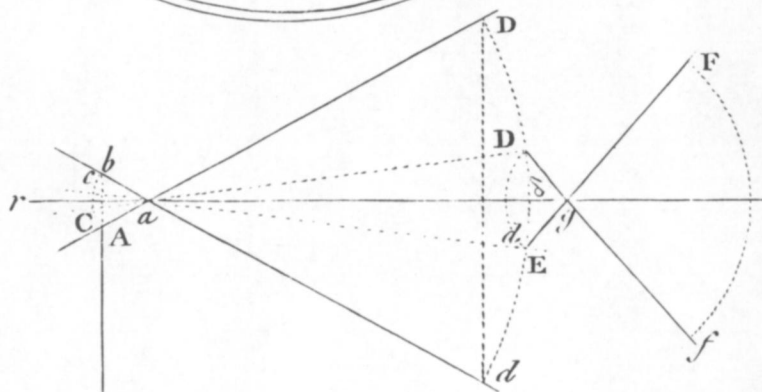
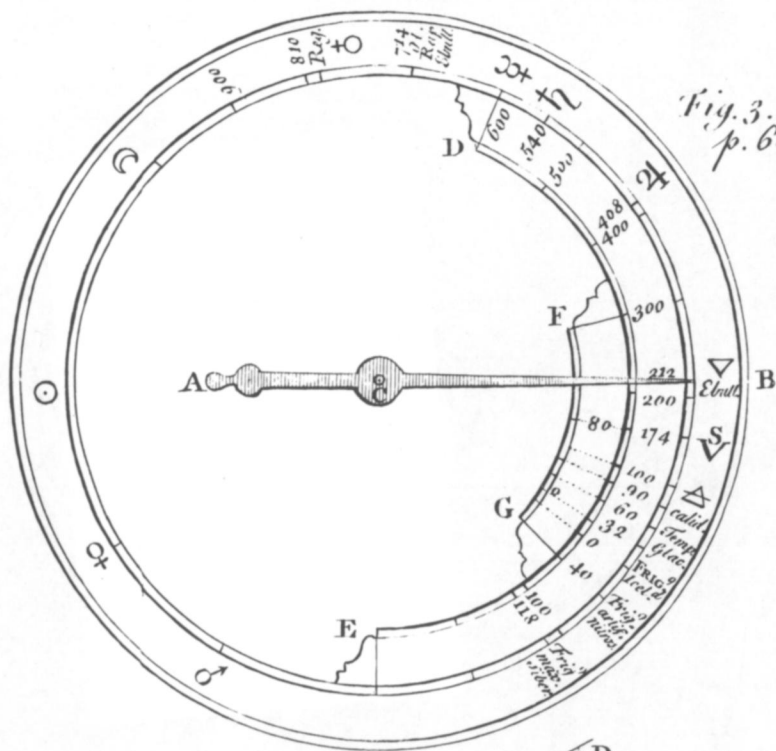
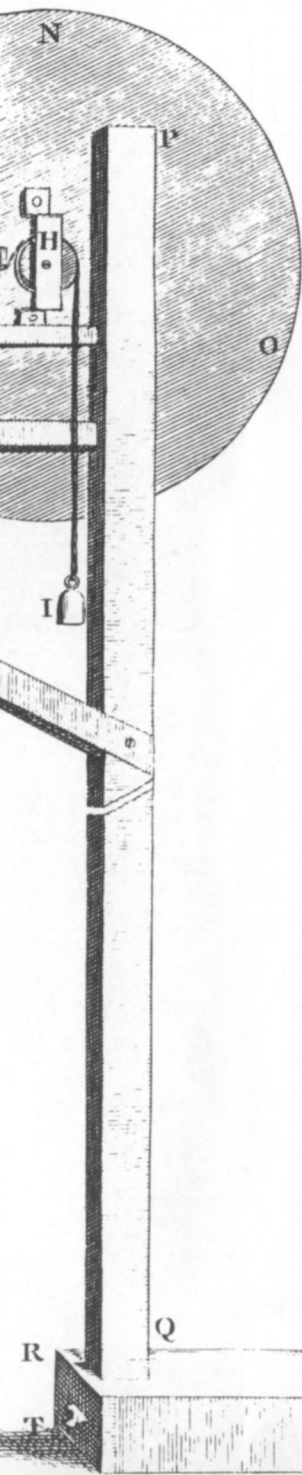


Fig. 2. p. 686.



opposed to each other, South to South; the Filings produced the same Appearance of Repulsion, as described in the fifth *Experiment*; then the Bars being brought so near as to touch each other at the same Poles, the Repulsion was instantly changed into Attraction.

III. *A Discourse concerning the Usefulness of Thermometers in Chemical Experiments; and concerning the Principles on which the Thermometers now in Use have been constructed; together with the Description and Uses of a Metalline Thermometer, newly invented by Cromwell Mortimer M. D. Sec. R. S. &c.*

Read May 8. 1735.
*here printed with some
 Alterations.*

CHEMISTRY being the most extensive Branch of Experimental Philosophy, hath furnish'd Mankind with the greatest Number of curious and useful Discoveries; for not only the Art of separating Metals from their Ores, of which Metals are form'd such Variety of useful Instruments, but likewise Cookery, which is so much concern'd about the Food of Mankind during Health, and also Pharmacy, which furnishes Medicines for the restoring Health when lost, the Art of Dyeing, and many other useful Manufactures, all owe their Improvements to this Science; many of which have been light on unexpectedly by the Operator, while he

he had something else in View : but in many Cases the Chemists complain, that, having once accidentally light on a curious Experiment, upon endeavouring to repeat it, they have never been able to make their Process succeed exactly, as it did the first time, notwithstanding that they made use of the same Materials, in the same Quantity, and conducted the Process thro' exactly the same Operations. Where then must the Cause of the Miscarriage lie ? Surely in the Degree of Heat made use of in the two Experiments : For, in many common Operations, how usual is it for a Preparation to be spoiled either by too little, or, most commonly, by too much Fire, too long or too short a time applied ! In order therefore to prevent these many Miscarriages, I would advise the Chemist, in his Operations, to observe his Clock with as much Exactness as the Astronomer doth in his Observations ; and in order to know to a Certainty the very Degrees of Heat he ever made use of in any Process, that so he may be able to repeat and continue the same again in any Repetitions of the same Experiment, let him have his Laboratory furnish'd with various Sorts of Thermometers, proportion'd to the Degree of Heat he intends to make use of. He will find these Instruments as useful to him in his Processes, as they have proved to the curious Gardener in his Stoves, who by them is taught to keep his Plants in the same Degrees of Heat, as are natural to them in their respective Climates ; which hath been set forth in Tables, after a very ingenious manner, by Mr.

* *Skeldrake of Norwich.* And besides the enabling him to perform his Operations with more Exactness, these Instruments would save him a great deal of Fuel; for as Liquors, while boiling, are not capable of receiving a greater Degree of Heat, all Fuel which is used more than to keep them in that State is useless; and the like happens in many other Cases.

These Instruments would also be of great Service to Maltsters, Brewers, Distillers, and Vinegar-makers; for, by Thermometers placed in different Parts of the Heap of wetted Malt, the proper Heat for its sprouting might be determined, and then regulated: The same for the Heat of the Kiln when the Malt is spread on it. By Thermometers the Brewer may ascertain the Heat of the Water when he pours it upon the Malt, the Heat of the Wort when he sets it to work, and the Heat while working: And in the like manner the Distiller and Vinegar-maker, in a Word, every Artificer, who employs Heat in his Business, may by these Instruments be certain of every Degree necessary in each Part of his Work.

Many Experiments shew, that all known Bodies, whether fluid or solid, increase their Bulk or rarefy by an Addition of Heat; and, on the contrary, contract or become more dense by the Diminution of Heat, which is the Presence of Cold: And these Alterations are always more or less sensible in proportion to the natural Rarity or Density of the Bodies. The

* Now Truss-maker over against the End of *Suffolk-street* near *Charing-Cross*, London, 1748.

The *Air* we live in, as it is the most rare and light Fluid, so are its Alterations the most sensible; and indeed I know of no Experiments which determine how far it is capable of being expanded by Heat, or condensed by Cold; only we find that it will make its Way thro' any Fluid in which it lay dormant, when its elastic Property is roused by the Approach of such an Heat as will make the Fluid boil. On the other hand, when compress'd by a Fluid so contracted by Cold, as to freeze, or become solid, its Elasticity will only bear a certain Degree of Compression, till the Force wherewith it endeavours to restore itself, exceeds the Force by which the Parts of the Solid, that confines it, adhere to each other, and so bursts its Prison; as we often see during hard Frosts in Ice, and likewise Glafs, and other hard Bodies, whose Parts cannot stretch.

Next to Air is *Alcohol*, or the highest rectified Spirit of Wine: This, Water, and all other Liquids, are capable of receiving no greater Degree of Heat than what makes them boil, as was first demonstrated by Monsieur *Amontons*, a Member of the *Royal Academy des Sciences* at *Paris*; but that ingenious Inventor of the Quicksilver Thermometer Mr. *Fahrenheit* hath discover'd, that when the Barometer marks a greater Pressure of the Atmosphere, the same Liquor will receive 8 or 9 Degrees more of Heat than when the Barometer is at the lowest. From hence the great Professor *Boerhaave* gives the Hint, that, from nice Experiments being made of the different Degrees of Heat mark'd by a Thermometer in boiling Water compared with the different Heights of the Barometer, and Tables formed
upon

upon them, a Thermometer applied to boiling Water might, at Sea, where the Motion of the Ship hinders Observations with the Barometer, serve to determine the Difference of the Gravity of the Atmosphere. See his *Chemistry*, Tom. I. p. 171.

These, and all other Liquids, by a certain determinate Degree of Cold peculiar to each sort, lose their Fluidity, and freeze, or become solid, but not in the same Order as by Heat they boil; for by Cold Oil or Water is sooner frozen than Spirit of Wine, tho' Spirit of Wine will boil sooner than Oil or Water. All solid Bodies likewise, as Minerals, Metals, and even Stones, will become fluid, or melt, at a certain Degree of Heat peculiar to each Species; and, when thoroughly melted, it is probable they are capable of receiving no higher Degree of Heat; and, on the Absence of that Heat to a certain Degree, they all return to their natural solid State. Hence we may reasonably conclude, that Solidity is the natural State of all Bodies; and that some are only accidentally fluid, because their Constitution is such as to melt by those Degrees of Heat which our Atmosphere is most commonly subject to. All solid Bodies are observed to contract themselves into smaller Dimensions by Cold, and gradually to expand themselves at the Approach of Heat, till at last, being by Heat forc'd to the greatest Degree of Expansion, the Particles of which they are composed losing their Cohesion, they become fluid, but no Experiments have yet been made, which determine whether Solids, exposed to Cold beyond certain Degrees, will cease to contract any more.

The learned Dr. *Muschenbroek*, Prof. of Astronomy at *Utrecht*, and *F. R. S.* hath lately invented a very ingenious

ingenious Instrument, which he calls a *Pyrometer* and which Dr. *Desaguliers* hath made some Improvements to * ; a full Description of which he hath given in his *Course of Experimental Philosophy*, Vol. I. p. 421. &c. By this Instrument the Elongation of Rods of several Sorts of Metals by the Approach of a certain Number of Flames of a Spirit-Lamp, and likewise their as sudden Contraction, on the extinguishing one or more of those Flames, is render'd sensible to the Eye: Which sufficiently evidences the Matter of Fact, and puts it beyond all Doubt.

From the above-mention'd Property of Bodies contracting and expanding in Cold and Heat, have all Thermometers been constructed, that have ever been made use of in order to observe and compare the different Degrees of Heat, either in our Atmosphere, or in other Bodies. The most simple and most sensible of any is that æreal Thermometer described by the great Mr. *Boyle*, in his New Experiments and Observations touching Cold, *Lond.* 1683. 4to. p. 39. It consists of a glass Bubble, with a very slender Stem not bigger than a Raven's Quill. The Bubble is left full of Air, and a few Drops of Water being convey'd into the Stem in an erect Position, will there remain suspended to a certain Height; but, by the least Addition of Heat, the Air in the Bubble expanding will push the Water up higher

* This Instrument hath since been greatly improved by that ingenious Watch-maker Mr. *John Ellicot*, F. R. S. See *Phil. Transf.* No. 443.

higher ; or, by the Approach of Cold, the Air contracting, the Water will fall lower in the Stem. This Instrument may be of Use in small Degrees of Heat, and in Cold, till the Water begins to freeze, when it becomes useless.

The next in Order of Sensibility is that first invented by *Cornelius Drebbelius* of *Alcmar*, and improved by *Boerhaave*. (See his *Chemistry*, Tom. I. p. 152, & 153.) It consists of an hollow glass *Lens* joined to a Stem of a larger Size than in the preceding, and a Basin into which the End of the Stem is inverted. The Air in the *Lens* must be so much rarefied, that the Stem being inverted into a tinged Liquor in the Basin, the Liquor will rise up some way in the Stem ; then, by the Application of Heat to the *Lens*, the Liquor in the Stem will be push'd down, and by Cold the Liquor will rise up. This Instrument will give Notice of the smallest Changes in the Air ; but it cannot be immersed into any Liquid for chemical Experiments, unless the Stem were made much longer, and bent down in Form of a Syphon : But even then it would be very unhandy, and, like the preceding, it would never serve for any Degree below what would freeze the Liquor made use of, nor for any above what would force out the confin'd Air through the Liquor in the Basin. Besides, both these Instruments, being subject to the Pressure of the Atmosphere, are not proper, without comparing the Barometer at the same time, to determine the Degrees of Heat at a great Distance of Time between each Experiment.

The

The most usual Sort of Thermometers is that described in the Account of the Experiments by the *Academy of Cemento*; which being the common ones, made of Spirit of Wine ting'd, it is needless to describe. The Bounds of the Degrees of Heat which these will measure, and which is commonly called the Range of the Instrument, are from the Degree which freezes Spirit of Wine, up to that which makes it boil. The Spirit-Thermometers, commonly made here in *London*, are so graduated, that when the Spirit is rarefied to the Degree that the most sultry Sunshine commonly known in our Climate of $51^{\circ}\frac{1}{2}$ N. Lat. can raise it, there is placed the Mark 0. or Degree of no Cold. Some few are mark'd 10 or 20 above this, if they are design'd to be used in hotter Climates; but all are graduated downwards from this: So that the 45° . is the Point of temperate, and 65° . is the Point of freezing, and 100° . is plac'd just above the Ball. But the most accurate Spirit-Thermometers are those lately made by the ingenious Mr. *Reaumur*, Member of the *Royal Academy of Sciences* at *Paris*; he hath taken a great deal of Pains, and used great Exactness, in fixing the certain Points of freezing of Water, of temperate Air, and boiling Water. He determines the freezing Point, by leaving his Thermometer a considerable time in Water, into which is put a good deal of Ice, at a time when the Water would not freeze of itself; and this he marks 0. or the Degree of no Heat; and his Scale is mark'd with Numbers running downwards from 0. measuring the Degrees of Cold, and upwards measuring the Degrees of Heat: At $10\frac{1}{2}$ upwards he marks

the Point of Temperate, which he determines by placing his Instrument in a subterranean Cavern, which is neither affected by Frost nor Sunshine, but is observed to keep an equable Temperature all the Year round; such as deep Cellars and Wine-Vaults commonly do. In boiling Water he finds that his Thermometer rises to his 80th Division,* or 80 Degrees, which are formed by dividing the Spirit when condensed to the freezing Point, into 1000 equal Parts; so that, with the Heat which makes Water boil, the Spirit is expanded only $\frac{80}{1000}$, more than with the Cold which freezes Water.

These Spirit-Thermometers are of Use in Experiments where somewhat greater Cold than the freezing of Water is required; but they can never be of Use in any Degrees of Heat beyond the boiling of the Spirit itself; because it then becomes volatile, or rises up in Steam, and not only expands no more, but likewise the Quantity is diminished by the Particles which fly up from the Surface of the Liquor, and are suspended in the Top of the Tube.

Many have filled their Thermometers with various Sorts of Oils†: These indeed will measure many Degrees above the boiling of Water, till they boil themselves; and then they have the same Defect as the Spirit

* But, with Submission to so great a Man, I cannot apprehend that his Thermometers, when the Spirits are raised up to 80 do mark any greater Degree of Heat than their own specific boiling Heat, which, if they are *Alcohol*, or the most rectified Spirits, answer to 174. of *Fahrenheit's* Scale; if of the Strength of common Brandy to 190.

† See Dr. *Martin's* Essays *Med. & Philos.* p. 225.

Spirit ones just mention'd, which is the Liquor losing of its Bulk by Evaporation; and they congeal much sooner than Water, and so are useless in measuring any Degrees of Cold.

The most useful Instruments, as they comprehend the largest Range, are the Mercurial Thermometers, which were brought into Use by that ingenious Artificer *Fahrenheit*, *F. R. S.* (See *Phil. Trans.* N°. 381.): But, to do Justice to a most worthy Member of the *Royal Society*, namely, Dr. *Halley*, he first gave the Hint, and even proposed the making Thermometers of Quicksilver long before *Fahrenheit's* Time (See *Phil. Trans.* N°. 197. p. 652.). However, *Fahrenheit* deserves Thanks from the World for having brought these Instruments into Use, because they will measure the greatest Degrees of Cold yet known; for no Cold hitherto observed hath been able to freeze or render *Mercury* solid: And in measuring Heat, they go far beyond boiling Water, even beyond the melting of Tin or Lead. *Fahrenheit* begins his Scale from 0. the Point to which the *Mercury* hath been observed to fall by the greatest Cold in *Ysland*; and computes, that the *Mercury* then * occupies 11124 Parts. This is his Point of no Heat. Then reckoning upwards from this, he finds that when the *Mercury* is rarefied only 32 Parts or Degrees more, common Water just begins to freeze: In a temperate Air it will rise to about 60. The most saltry Sunshine seldom raises it to 90; the Heat of an animal Body to 96; the boiling of *Alcohol* to 174; the boiling
of

* See *Beerh. Chem.* Tom. I. p. 174.

of Water to 212; and before the *Mercury* itself boils, it will rise to 600.

I cannot here forbear giving an Abstract of a very curious and surprising Experiment of *Fahrenheit's*, concerning the artificial Production of Cold, as it is related by *Boerhaave* in his *Chemistry*, Tom. I. p. 164. *Fahrenheit* had a *Mercurial* Thermometer made with so long a Stem, that he could carry down the Scale 76 Parts or Degrees below 0. With this Instrument he found, that Cold might be produced by gradually pouring Spirit of Nitre upon powder'd Ice, till the *Mercury* would subside to 40° below 0. that is 72°* lower than the Cold which freezes common Water. *Boerhaave*, in his *Chemistry*, Tom. I. p. 161. mentions a very pretty Way of determining the freezing Point: He advises to hang the Thermometer free in the open Air, not against any Wall or Building; and near it you must hang a Piece of very fine Linen or Muslin just dipp'd in clean Water: When this begins to grow stiff, you will find the *Mercury* stand at about the 33d Degree; and it will also stand at the same Height when an hoar Frost appears upon the Ground; which he looks upon as a certain Sign of the Beginning of freezing.

Having thus given an Account of the several Sorts of Thermometers hitherto used, and what Degrees of Heat they are proper to measure, we find none of them capable of measuring the greater Degrees of Heat, which are the most commonly made use
of

* But what is this to the marvellous natural Cold of *Siberia*, 120°. below 0? See the Preface to *Gmelin's Flora Siberica*. *Petrop.* 1747. 450.

of by the Chemists in many of their Operations. Besides, all the above Instruments, being made of Glass, are easily broken by Accidents, and as liable to crack of themselves, by being taken out of a great Heat, and too suddenly exposed to Cold. I therefore consider'd whether the above-mention'd Property of Solids, and especially of Metals contracting with Cold, and expanding with Heat, might not be applied to the Construction of an Instrument capable of measuring all Degrees even of the greatest Cold, as well as the greatest Heat, to the melting Copper or Iron, which require more Heat than any other Metals to melt them. Altho' the Alterations in Metals are but small, in respect of those in Spirits, or even *Mercury*, yet it being found, that Iron, *e. g.* becomes $\frac{1}{60}$ longer * when red-hot, than when of its natural Temperature; and Dr. *Derham*, in his last Paper read before the *Royal Society* concerning the Vibration of *Pendulums*, says, that a Rod $39.\frac{126}{1000}$ Inches long, becomes $\frac{1}{10}$ Inch longer than its natural Dimensions in temperate Air, by being exposed to Heat equal to that of an human Body; $\frac{2}{1000}$ Inch longer in hot Sunshine; that it was $\frac{2}{100}$ or $\frac{1}{50}$ Inch longer than its natural State, by being heated in a flaming Heat; that it became $\frac{2}{1000}$ shorter than its natural Length by being quenched in cold Water; and still $\frac{3}{1000}$ shorter, by being put into a Mixture of Salt and Snow. From which Experiments one may conclude, that from *Fahrenheit's* Cold of 40 below 0. to the greatest Heat Iron can bear without melting, a Rod of three Feet long will have about $\frac{1}{4}$ Inch Increase; which Increase of Length will be Range
enough

* Vide *Sturm. Cell.*

enough to make all the intermediate Degrees observable upon an Instrument.

Suppose in *Fig. 1. TAB. II.* *AB* a Rod of Iron at its natural Length by the Heat of the Atmosphere, placed upright upon one End; upon the Point of that rests a Bar *CD* moveable on an Axis at *a*; and that, by making a Fire about the End *B* of the Rod, till it is just ready to melt, the Rod will increase in Length *Ab*, and consequently push the Bar into the Situation *cd*. Now it is obvious to any one who understands ever so little of Mechanics, that tho' the Elongation of the Rod *Ab* be even scarce perceptible to the Eye, yet if upon the Bar *CD* the Distance *aA* from the Axis to the Place where the Rod *BA* pushes against it be very small, and the other Part of the Bar *aD* very long, the Arch *Dd* may be increased at Pleasure, so as to bear to be divided into any Number of Divisions that shall be found necessary: For the Arch *Dd* will always be to the Arch *Cc* in the same Proportion as the Distance *Da* is to *aC*; and likewise the Chords of these Arches *Dd* and *Ab* will be in the same Proportion; γ, δ , is the Situation of the Lever on the Level; and if it be found inconvenient to make the Arm *aD* so long, as to make very minute Alterations in the Length of the Rod *AB* easily observable, this Inconveniency may be readily removed by having a second Bar *EF*, turning on the Axis *g*, whose Arm *gE* bearing up against the Extremity *D* of the first Bar or Lever, will rise with it, or be press'd down by it; and the other Arm *gF* being lengthen'd at Pleasure, the Arch *Ff* will be as large as you find convenient; or even a third and fourth Lever may be added.

When

When I first designed to have an Instrument constructed answering to the foregoing Principles of *Fig. 1.* I drew a Figure of it, wherein I proposed the Lever *AD* to have terminated in two Arches of Circles made out of one Piece of Brass; the smaller Arch formed on the Radius *aA* to be loaded with a Quantity of Metal sufficient to overcome all the Friction of the several Parts, so as to press down with a considerable Weight, and always to rest upon the Point *A* of the upright Rod *AB*; at *a* the Axis, on which they were to turn; and the larger Arch form'd on the Radius *aD*, was proposed to be a Sextant, the outward Edge of which was to be toothed, which Teeth were to play into the Teeth of a small brass Wheel carrying a steel *Index* like the Minute-hand of a Clock, which small Wheel with the Hand was to make one Revolution nearly by the utmost Rise and Fall of the Sextant at *D*; or, instead of Teeth, I proposed a Piece of a Watch-Chain to be fasten'd to the upper Limb of the Sextant, and so to be brought downwards, and passing nearly round the small Wheel in one Groove, to be fasten'd to it: In another Groove in this small Wheel was another Piece of Watch-Chain to be fasten'd, which, being passed contrarywise round the said Wheel, was to have a Weight hung to it that would be a Counterpoise to the Sextant; but, upon consulting my two ingenious Friends Mr. *Geo. Graham* and Mr. *John Ellicot* two worthy Members of this *Society*, they each of them persuaded me to lay aside that more complexed Construction, and to have the Instrument made in the plain and simple manner in which Mr.

Jackson

Jackson executed it for me in the Year 1736. as is represented in *Fig. 2* and 3. TAB. II.

The Description of the Instrument.

Fig. 2. *AB* a round Rod of Steel or Brass a Quarter of an Inch thick, and 3 Feet 1 Inch long: When the Rod is of Brass 3 Feet long, the Point *A* must be of Steel 1 Inch long, to prevent its wearing away, or losing its Point; which conical Point is made to screw on and off.

I had the first Rods made $1\frac{1}{2}$ Inch thick at *B*, and of the same Thickness 6 Inches up; but I found Inconveniences from that Form, and that a Rod all of a Size was better.

CD, cd, are two iron Supporters, joined by a flat cross Bar at Bottom *Dd* two Inches long, in the middle of which is a Point $\frac{1}{8}$ Inch high under *B*, which goes into an Hole at the Bottom of the Rod *B*, and serves to keep the Rod in its Place at Bottom, as the cross Bar ** having an Hole in it, thro' which the Rod passes, does in the middle or about $\frac{2}{3}$ up the Supporters, and the Point *A* goes into a small Hole in the under Side of the Lever; all which keep the upright Rod firm and steady in its Place. The iron Supporters are flat, or parallel to the Front of the Machine from *C* to *X* and *c* to *x*, where they are twisted half-round, so that the lower Parts *XD, xd* stand at right Angles with the upper Parts. This Contrivance gives the freer Access to the Rod for the Sand or Fluid into which the Machine is set to measure the Heat of it, the Supporters standing 2 Inches asunder at *Dd*; and that the Degrees of Heat

may be compared uniformly in different Experiments, the Bottom of the Rod must always be immersed to the same Height in the Matter to be examined; and therefore I make a Mark, a small Furrow † quite round the Rod, $1\frac{1}{2}$ Inch from the Bottom *B*. For the deeper the Rod is immersed into any Matter, it will be lengthen'd the more by the same Degree of Heat.

EF, the Lever, which turns upon an Axis *G*. At *F* is fastened a String, which, passing twice round the small Pulley *H*, has a Weight *I* hanging to the other End of it, of about half a Pound, being enough to keep the String always stretch'd. At the other End *E* of the Lever is hung another Weight *L*, which must be heavy enough not only to counter-balance the longer Arm *GF*, but press down upon the Point *A* with a Weight sufficient to keep its steady.

MNO, is the back Part of the Plate, like the Dial-Plate of a Clock made of Brass. See the Front of it at *Fig. 3*.

The Pulley *H* turns upon an Axis *C* in *Fig. 3*. which goes thro' the Plate, and on the other Side or Front of the Dial-Plate carries a Hand or Index *AB* in *Fig. 3*.

N. B. *G* being the *Fulcrum* of the Lever, the Distance *GA* being very small, and the Distance *GF* being very great, the smallest Motion at *A* will produce a very great one at *F*, and therefore the Index will turn very sensibly upon the Plate.

The Proportions of the Rod and Lever are discretionary; my Rods both of Steel and Brass are 3 Feet long in one solid Piece, but they have each a Point or Cone of Steel 1 Inch high, that screws

Uuuu

upon

upon the Top at *A*. The Lever has 4 Inches from *E* to *A*, $1\frac{1}{7}$ Inch from *A* to *G*, and 12 Inches from *G* to *F*; the Distance of *G* above *c* is $1\frac{1}{2}$ Inch, the brass Pulley *H* is $\frac{1}{2}$ Inch Diameter; all the other Parts of the Machine are of Oak. The main Support or Pillar *PQ* is 1 Inch square, $2\frac{1}{2}$ Feet high, and at Bottom is let thro' a Groove at *Q* made in a great heavy Block or Pedestal of Wood *RS*. In this Groove the Pillar may be raised higher or lower, in order to adjust the Height of the Pillar to the Situation, which the Bottom of the Rod *AB* may require in different Experiments; and it is to be fixed in that Place by a Screw at *T*, which goes thro' the Front of the Block, and presses against the Bottom of the Pillar.

Fig. 3. represents the *Dial-Plate*, or Front of the Plate mark'd *MNO*: In *Fig. 2.* it is a Plate of Brass, with strong Paper glued upon it, and may be of what Size you please; mine is 11 Inches over.

AB is the Hand or *Index*, which slips on very stiff upon the Axis *C*, that carries the Pulley *H* in *Fig. 2.* The outer Circle is to be left wide enough to contain the chemical Characters or Marks which are to be made upon it, the Arch *DE* contains the Divisions of *Fahrenheit's* Mercurial Thermometer; the Arc *FG* those of *Reaumur*, or 'the Spirit of Wine Thermometer.

In order to adjust this Instrument for Use I place the Bottom of the Rod *B* in *Fig. 2.* immersed up to the Mark \dagger in cold River or Rain-Water, in a Vessel proper to be set over the Fire; and when it

has

has boiled for a Quarter of an Hour, I turn the Index *AB* in *Fig. 3.* till it stands in the horizontal Position, as at *B*, being the Point of boiling-hot Water, and which answers to Division 212 on *Fahrenheit's* Arch. I then take it out of the Water, and dry it, by holding it a little over the Fire: And now great Care must be taken, that nothing alters the Situation of the Index upon the Axis; even a Nut to screw on upon the Axis at *C* may be the best to keep it fixed. If the Instrument be left to cool in the Air, the Index will fall below *B*, shewing the Degrees of Cold, or less Heat than boiling Water; and if put into melting Tin, Lead, &c. it will shew the Degrees of Heat above boiling Water. A brass Rod will serve for an Instrument to measure the greatest Degrees of Cold, and all the Degrees of Heat, to the melting of Silver or Gold; but if you have a Mind to make one to measure greater Degrees of Heat, the Rod must be of Steel, or the finest Iron. A Rod of Brass, according to Dr. *Muschenbroek's* Experiments, *l. c.* was found to lengthen 377, when one of Iron lengthen'd only 230 Parts. An iron Rod, being regulated by boiling Water, as above directed, will measure not only the Heat of melted Tin and Lead, but of Silver, Gold, and Copper, and will even shew the Degree when Iron itself begins to melt, which will be the greatest Degree of Elongation of the Rod just before the Bottom of it runs; and I imagine, that an Instrument may be constructed with Supporters, and a Rod made of Tobacco-pipe Clay, which, being regulated by boiling Mercury (for it must never touch Water), may

be adapted to measure still greater Degrees of Heat, till the Materials themselves melt into Glas.

I should advise, that not only the Scale of this sort of Thermometer, but likewise of all others, be determined by Experiments, without regarding any Equality as to Measure between the Divisions, and that in every Individual that shall be made; for a Difference in the Length and Thickness of the Rods in this sort will make a Difference in the Scale, as much or more than the Inequality in the Cavity of the Stem, or glass Tube of other Thermometers, which can never be just, if applied to a Scale whose Divisions are made equal; unless the Cavity of the Stem be perfectly equal, which it is impossible for any Workman to undertake to do, and which is very seldom, if ever, hit on by chance. Therefore, in these Instruments, let the Point *B* in *Fig. 3.* or the horizontal Position of the Index, be the Situation of the Index when the Rod has stood a Quarter of an Hour in boiling Water; there mark ∇ *boiling* on the outer Circle; on *Fahrenheit's* Arch mark 212. then set your Machine up to the Mark $+$ into melting Tin, which is the Metal that melts easiest. When the Rod is arrived to its greatest Elongation in that Metal, inscribe the Character γ on the outer Circle; do the like with Lead, and set the Character η at it. At the boiling of Mercury put the Mark Φ , and on *Fahrenheit's* Arch mark 600. the utmost Extent his Mercurial Instruments can measure: Then proceed to the melting of Silver, and set the Mark ζ ; at the melting of Gold place the Mark \odot ; at the melting of Copper place the Mark Ψ ; at the melting of Iron place the Mark δ , the most difficult to melt of all Metals.

As the Divisions pointed out by the Index will be different with Rods of different Metals or Substances, you may make different Circles upon the Plate for the Range of the different Rods, and mark them; the Iron Rod, the Brass Rod, the Clay Rod; and set the several Marks above specified upon each Circle apart; or you may, to avoid Confusion, have a different Instrument for each kind of Rod.

Being obliged to take down my *Athanas* and Wind-Furnace, upon removing twice to different Houses, and not having rebuilt them where I now live, I have not had Opportunities yet of fixing the Scale of my own Instrument, which was one Reason why I did not publish an Account of my Invention sooner; for I hope hereafter to be able to compare the Degrees of Heat necessary for the melting of each Metal, and to determine the Question whether Metals in the highest Degree of Fusion are susceptible of greater Degrees of Heat by increasing the Fire, as Water thoroughly boiling can never be made hotter; nor did I intend to have publish'd any Description of this Instrument till I had completed Tables of the Degrees of Cold and Heat, from *Fahrenheit's* Experiment of Cold produced by Art 40 Degrees below 0 to the Heat of melting Iron.

According to *Fahrenheit's* Scale, the Heat of the strongest Sunshine is at about 80. Spirit of Wine boils at 176. Water at 212. the *Lixivium* of Salt of Tartar at 240. Spirit of Nitre at 242. Oil of Vitriol at 346. Quicksilver at 600 *.

As

* See Augustin. Grischow *Thermometria comparata accuratius, & Harmonica*. Berolini 1740. 4to. p. 10.

As all chemical Digestions, where an equable Heat is to be continued for some time together, will come in between hot Sunshine and the boiling of Quicksilver, a Thermoscope of that Range will be sufficient for common Uses; and therefore one fitted with a brass Rod will answer these Purposes.

In large Furnaces for running down Ores, or melting great Quantities of Metal together, it is not possible to place such an Instrument; but then in Lead and Tin there may be small Outlets contrived, into which some of the melted Metal may be permitted to flow, and remain in Contact with the same Body of Metal within, where the Instrument may be placed; and for placing a Thermoscope in Iron, Copper, or Glass Furnaces, there may be a Place contrived, which shall not open into the Furnace, but have the Thickness of a Stone or Brick left between, upon which the Instrument may be plac'd; and tho' in such a Situation it will not measure the actual Heat within the Furnace, it will always give the relative or comparative Heat in the like Circumstances at different Times, and so shew us how to regulate the Heat within.

Altho' a Chemist shall have one of these Instruments to measure the Heat, he shall have used in any Experiment, and have noted down the several Degrees made use of, and the Time each lasted, he still labours under another Difficulty, which is the not being able to command any required Heat, and that it shall last a certain required Time, unless it be below that of boiling Water, which may be procured and continued by various Contrivances of Lamps, either of Spirits, or of Oil; but how to continue a Fire for 12 or 24 Hours together, without Attendance, which shall continually keep Quicksilver boiling,

boiling, Lead in Fusion, or may be let down so low as not to exceed the Heat of Sunshine, and then be raised again, and that without letting out the Fire, or moving the Vessels, may seem almost impracticable; but by an Improvement of the Furnace the ancient Chemists call'd their *Athanas*, I hope to succeed in it, which may be the Subject of another Paper.

The Rev. *Stephen Hales* D. D. that most worthy Member of the *Royal Society*, to whom the World is greatly indebted for many accurate Experiments, and useful Discoveries, upon hearing the Minutes of my Paper deliver'd in to the *Royal Society*, on May 8. 1735. read upon the *Thursday* following, desired me to lend him the Original for some Days, telling me he had some Thoughts of making a Thermoscope with a Rod of Lead. After a few Days he returned me my Paper, with the following obliging Letter, and kind Remarks.

S I R,

I HAVE read over your *Thermometrical Tract* with Satisfaction, and believe it will be of good Use. The Want of ascertaining the Degrees of Heat and Cold is a great and important *Desideratum* in Experimental Philosophy.

What I intended to do was only this, *viz.* to get a leaden Wire, of such a Size and Strength as to bear its own Weight, to have it as long as the longest Gun-barrel I could procure, and to have it sustain a Lever as you have done; then to pour boiling Water into the Barrel, for a long time, till the Lever
rises

rises no more; the Water to have Vent at the Bottom, yet so as to have the Gun-barrel always full of Water; the Breech-Pin to be out, and the leaden Rod to rest on a Piece of Wood set upright, according to the Course of its Fibres, not sideways.

To give at the same time to a Mercurial Thermometer the Heat of boiling Water.

Then to take the freezing Point of the Leaden and Mercurial Thermometers; and afterwards to graduate all the intermediate Degrees, from the Mercurial Thermometer upon the Leaden Thermometer, as they occur.

Thus a Standard Thermometer may be made to graduate others by; but I will not now set about it, since you have undertaken the Subject.

His *Remarks* on the foregoing Paper.

Page. 673. *Thermometers* must be of excellent Use in Garden-Stoves; but foreign Plants must not be kept in an equal Degree of Heat in Stoves, to that of their native Country; *viz.* because they cannot bear as great a Heat in a confined close Air, as in an open free Air. - I have been told of Coffee-Trees being killed here in *England* by this Mistake: Such Plants must doubtless be kept warm*, but not so warm as in their native Country.

P.

* I should think it best to lessen the Heat in Stoves towards the Night, and so to keep the Plants exposed to less Degrees of Heat a-nights than a-days, nay to vary the Heat daily, or to endeavour by Art to procure different Degrees of Heat, agreeable to the natural Vicissitudes of the Climate the Plants come from, having Regard both to the Seasons of the Year, and the State of flowering or Fructification of the Plants; so that the best Way of ranging Plants in Green-houses or Stoves is according to the Climates they come from; for which Mr. *Sheldrake's* Tables above-mentioned, p. 674. must be of excellent Use. C. M.

P. 676. [*All solid Bodies are observed to contract with Cold.*] I have found that Wood does not contract or dilate lengthways with Heat or Cold. I am told that Mr. *George Graham* [is about making] this Experiment, as I am also, in order to regulate *Pendulums*.

P. 682. I fear that *Boerhaave's* wet Linen, which is so thin, may begin to freeze before all the *Mercury* or Spirit of Wine in the Ball of the Thermometer has the same Degree of Cold: Tho' hanging there long before and after freezing will bring it pretty near.

P. 683. [*A Rod of Iron 3 Feet long will have about $\frac{1}{4}$ Inch Increase*] or $\frac{1}{144}$ th Part.

IV. *A Continuation of a Paper concerning Electricity, by William Watfon F. R. S. printed in these Trans. N. 477, Article I. ending p. 501.*

Read Feb. 6.
1745-6.

AS Water is a Non-electric, and of consequence a Conductor of Electricity, I had Reason to believe that Ice was endowed with the same Properties. Upon making the Experiment, I found my Conjectures not without Foundation; for, upon electrifying a Piece of Ice, wherever the Ice was touched by a Non electric, it flashed and snapped. A Piece of Ice also held in the Hand of an electrified Man, as in the before-mentioned Processes, fired warm Spirit, chemical vegetable Oils, Camphor, and Gunpowder prepared as before. But here great Care must be taken, that,

Xxxx

by